Journal of the Royal Society of Western Australia, Vol. 65, Part 1, 1982, p. 17-24.

Some aberrant australite forms from Western Australia

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Manuscript received 19 August 1980; accepted 18 November 1980

Abstract

Australites which cannot be classified according to the shapes inherited from primary bodies and the recognised modifications resulting from aerodynamic and terrestrial processes are regarded as aberrant. Some aberrant australites appear to be solitary examples of their kind; others are represented by many specimens and can be classified into general types. Aberrant australites of interior Western Australia are closely similar in their specific gravities to other australites from the same area. The dimensional proportions of some types are characteristic. A knowledge of the abundance and distribution of aberrant australites in eastern Australia could be advantageous when considering the manner of their development.

Introduction

Most australites which are in reasonably well-preserved condition may be classified morphologically according to the first or both of the following factors:

(a) The shape seen when looking along the line of flight. Round, oval, boat, dumb-bell and tear-drop shapes which are most commonly recognised are directly related to the forms of the australite primary bodies.

(b) The modifications of the original primary shapes caused by aerodynamic processes during oriented flight in the atmosphere and terrestrial processes of weathering and erosion since arrival on the earth's surface e.g. flanged forms, lens forms, indicators and cores.

After classifying a collection along the above general lines, there are usually a few specimens which do not conform to those simple concepts of classification by being, for example, "flat-topped" or "oblique-ended". Such shape features were not inherited from known primary forms; nor are there obvious ways in which they might have been developed by later processes. Moreover, the flight orientations of these specimens are not always determinable with confidence and have sometimes been inconstant. These australites are generally referred to as aberrant forms or simply as "aberrants".

Few figures are available on the abundance of aberrant forms. In some recent studies of localized collections from interior Western Australia, the numbers of morphologically classifiable specimens and percentages of aberrant forms amongst them were as follows:—

Earaheedy station	876	3.3%
Hampton Hill station	2524	1.9%
Edjudina station	1000	3.5%
Mount Remarkable station	100	3.0%
Total:	4500	Mean: 2.6%

Baker (1969) found 6 aberrant out of 261 named specimens or 2.3% of australites from Mulka, South Australia, but only 10 aberrant out of 733 named specimens or 1.4% of combined collections from various localities in south-west Victoria (Baker 1956). Collectively, the aberrant forms are sufficiently abundant not to be regarded as rarities, though the word would certainly apply to some of their less common varieties.

About 200 aberrant specimens were considered during the present investigation but more than 100 of them were rejected as being too broken or worn to be informative. The collections represented are as follows: the South Australian Museum (SAM), the Western Australian Museum (WAM), the Geology Department University of Melbourne F. B. Allen collection (UM), Geology Department, W.A. School of Mines collection (SM), the private collections of Mr and Mrs R. G. Tillotson and Mr L. D. Tillotson (TC), Mr J. L. C. Jones(JLCJ), Mr J. B. Mitchell (JBM), Ms N. Moylan (NM), Mr P. J. Simmonds (PJS), and the E. S. Simpson collection held at the Western Australian Museum (ESS).

The literature on aberrant australites is almost non-existent, comprising generally the briefest mentions and an occasional illustration. Baker's (1969) illustration of aberrant forms from Mulka, South Australia and proffered explanation of their development is exceptional.

Classification of aberrant australites

The aberrant australites are here divided into two broad and very unequal groups.

Group 1.—These are forms known to the writer by only a single specimen and are therefore, perhaps, the product of some rare and accidental happening such as a collision in flight or a fragmentation followed by the adoption of a steady flight orientation and the development of a fragment as an individual. The word "aberrant" is usually defined as "straying from the right path" or "deviating from the normal" and it is to seemingly unique individuals that the word appears most appropriate because they approach most closely a "freak of nature". The examination of almost any large collection is likely to reveal a shape not previously encountered. The number of these specimens is relatively small and may be reduced by further observations or reports. Thus the "tailed" or "beaked" core was unique in my experience when reported (Cleverly 1974) but two further examples have since been examined and the type may now be relegated to the second or repetitive group of aberrant forms reported below, or even removed from the aberrant group altogether. The three specimens had a common flight orientation and with the advantage of that observation an alternative, and hopefully a more acceptable, explanation for the development of the form by processes normally contributing to australite development has become possible. The view is taken that if development of the form can be explained in an acceptable way by such processes, then use of the word "aberrant" is no longer necessary.

Group 2.—This more populous group contains those aberrant forms known by at least a few and sometimes by many specimens. The propriety of applying "aberrant" to these specimens is doubted. Here, it is not so much a case of nature straying from the normal as of our simple concepts of morphogenesis and classification being inadequate. When a shape feature is found to occur time and again, it should be the aim to explain its development and incorporate it in the general theory. The commonest aberrant forms occasionally constitute a per cent or so of classifiable specimens e.g. the "nut-like" form, 5 out of 261 named specimens or 1.9% at Mulka (Baker 1969) and 7 out of 876 or 0.8% at Earaheedy station (unpublished study). If Baker's explanation for development of the form is acceptable, then it is merely necessary to note that minor instabilities in flight may include rocking on the longer axis normal to the line of flight. This will account for a distinctive pattern of flow ridges instead of the more usual concentric (ring wave) or helical patterns; the helical pattern itself on some specimens is probably to be explained as resulting from a different minor instability—an axial wobble (Chapman *et al.* 1962).

Descriptive notes

Group 1.

Brief statements of examples from this group are given in Table 1. The specimen numbers used in the additional notes below are those of the Table.

1. (Figs. 1A1 and 1A2).—The flight orientation is unknown. The convex side is the more likely to have faced forward. The shape suggests a piece of stress shell or fragment of a hollow form (*e.g.* Figs. 1B1 and 1B2) aerodynamically modified, but by the time that flight conditions led to cooling and detachment of stress shell they would no longer favour ablation stripping and development of the form.

2. (Figs. 1C1 and 1C2).—"Discoidal" is used in the description to mean like a disc but much thicker and lacking flange (Baker 1959 p.33) as with a highly oblate spheroid. The flight orientation is unknown, the two major surfaces being much alike and lacking features such as flow ridges or flow swirls, which are indicators of anterior or posterior surface and thence of flight orientation. The specimen is too large and heavy and too rounded in the elevational profile to be a lens yet it shows no signs of having lost a stress shell and is proportionately too shallow to be a core. Discoidal, highly oblate spheroids are not generally recognised as being represented amongst australites though they are common forms of some other tektites (Baker 1959, Table 1).

3. (For illustrations, see Cleverly 1973 Fig. 2-43 and P1.1-43).—The coarse pattern of flow ridges is probably on the anterior surface. The parental form was evidently discoidal.

4. (Fig. 1D).—The well-shaped core portion of the specimen contrasts with the other half which looks almost as if plastically deformed, a possibility which is not only completely at variance with accepted concepts of very shallow aerodynamic heating but is scarcely possible for only one half of the specimen.

5. (Fig. 1E).—The flight orientation is unknown. Elongated indicators which have retained a piece of stress shell wrapping partly around one end are sometimes abraded until they have a smooth bulhous end, but this specimen shows no sign of having possessed a stress shell and appears to be of completely different development.

Table 1

Aberrant australites from Western Australia, Group 1

No.	Form	Collection	Locality	Dimensions (mm)	Mass (g)	S.G.
1	Centrally thickened, dished form with two unequal, non-opposed scallops in edge	JLCJ	Edjudina station	(26·2–23·2) x 9·2 Glass thickness 5·5 mm in middle of form, c. 3 mm near edge	4·462	2·453
2	Discoidal	TC ..	Kambalda	(24·9–24·0) x 9·6	7·083	....
3	Flow-ridged, plano-convex form, initially discoidal	SM 10610	Wonganoo station	(21·6–20·5) x 9·4	4·564	....
4	Elongated core tapering off obliquely and somewhat asymmetrically	SM 11714 .	Mount Remarkable station	42·4 x 18·0 x 15·1	15·147	2·463
5	Clublike	JLCJ	Hampton Hill station	....	....	
6	Clublike (air bomb?)	PJS No. 150	Kurnalpi	....	12·341	2·415
7	Lens with nearly diametral flow ridge across anterior surface	SM 12004 .	Menangina station	(13·4–12·9) x 9·4	1·649	2·449
8	Canoe?	UM	Eastern Goldfields	19·2 x 11·4 x 9·3	2·318	2·453

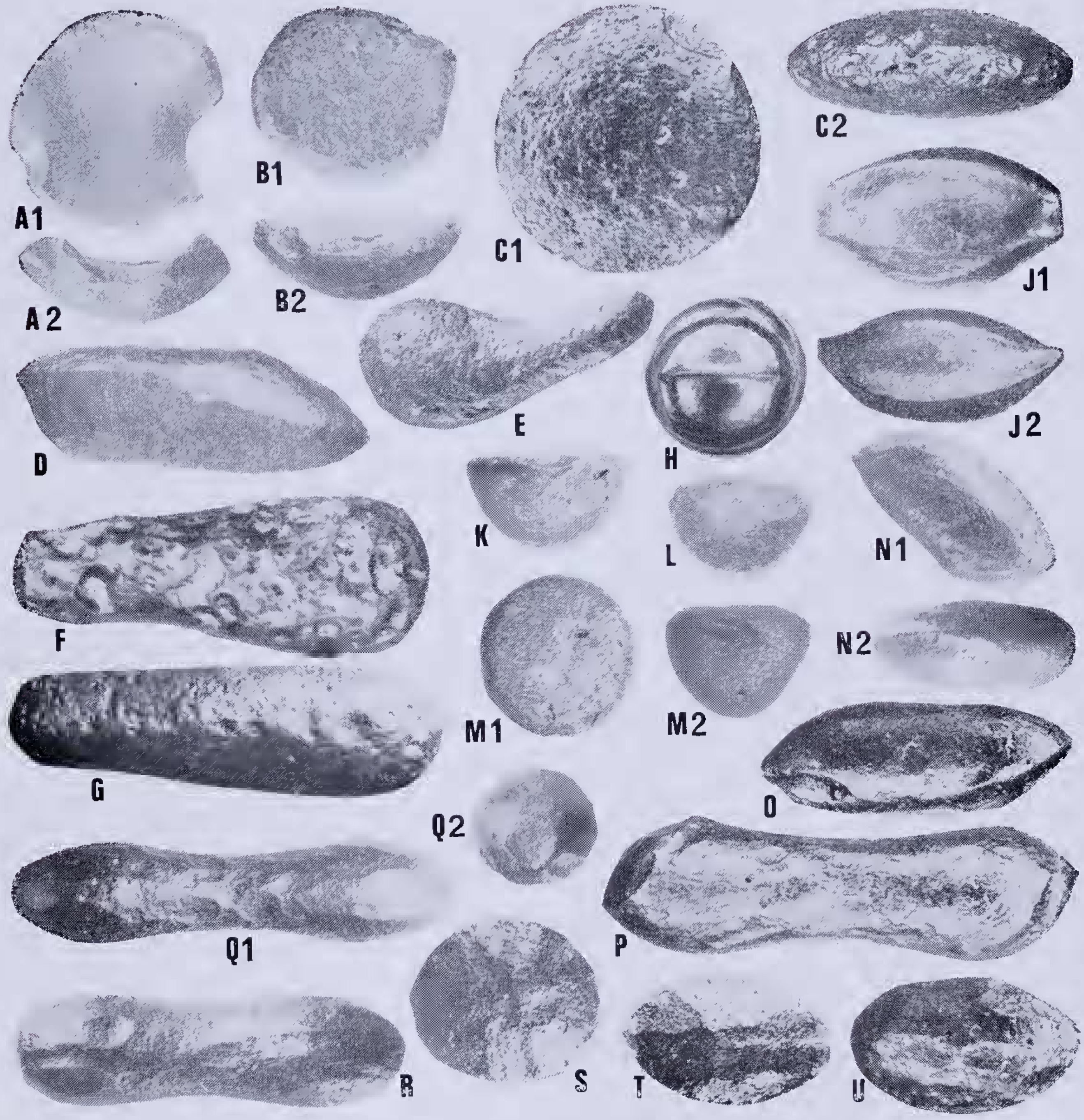

Figure 1.—Aberrant australites from Western Australia. For dimensions and key to specimens Nos. 1-8 see Table 1; for No. 9 onwards see Table 2. A1.—No. 1, concave side. A2.—No. 1, edge view. B1.—Fragment of hollow form, concave side, length 17.3 mm, Edjudina station, JLCJ. B2.—Fragment of hollow form, edge view. C1.—No. 2, one of the major (unidentified) surfaces C2.—No. 2, edge view. D.—No. 4. E.—No. 5. F.—No. 6. G.—Very weathered, elongated core, side view, obliquely illuminated to show shallow remnants of flake scars, length 64 mm, Earaheedy station, SM 10943. H.—No. 7, anterior surface. J1.—No. 8, posterior surface. J2.—No. 8, side view. K.—No. 9. L.—No. 10. M1.—No. 11, the flat "top" with bevelled edge, M2—No. 11, side view, N1.—No. 13, side view in supposed orientation for flight towards bottom of page. N2.—No. 13, "plan" view assuming N1 is correctly oriented, showing worn flow ridges on oblique end. O.—No. 15. P.—No. 16. Q1.—No. 17. Q2.—No. 17, flatly concave end. R.—No. 19. S.—No. 20, posterior surface. T.—No. 21, posterior surface. U.—No. 22, posterior surface.

6. (Fig. 1F).—Some specimens of this general shape have been called "air bombs" and are said to orient in flight with the larger end forward. However, it is improbable that such a body with an approximately hemispherical forward end could satisfy the stability requirements enunciated by Chapman *et al.* (1962 p. 14 *et seq.*). Some so-called "air bombs" have faint traces of a rim or a row of flake scars running lengthwise around them, showing that they were asymmetrical boat or dumb-bell bodies which were oriented with the long axis approximately normal to the line of flight (Fig. 1G). The specimen under discussion cannot be dismissed with that explanation.

7. (Fig. 1H).—The distinctive and very well-preserved feature (flow ridge?) across the anterior surface of this lens is not complemented by a similar one on the posterior surface which is severely etched and thus in contrast to the anterior surface.

8. Canoe? (Figs. 1J1 and 1J2.—This form is more stoutly constructed than normal canoes. It is less elongated (length/width 1.68) and proportionally wider (width/thickness 1.23) than the canoe-like form of Group 2 below, but it has the seed-type pattern of flow ridges on the anterior surface as does that form.

Group 2

The specimen numbers refer to Table 2.

Flat-topped form (Nos. 9-12, Fig. 1K to M).—A round form with a flat top over a rounded, bullet-like nose. The flight orientation is unknown and hence the "top" is not necessarily a posterior surface. The top may be faintly concave (e.g. No. 10 has overall thickness 5.4 mm, glass thickness at the axis 5.1 mm). A bevelled edge may be prominent (Figs. 1M1 and 1M2). The flat tops are not the result of fracturing and severe erosion would tend to round rather than flatten a surface. Round conical cores can approximate to the shape of this form, but even if severely abraded, the convexity of their posterior surfaces is generally evident and the conical surfaces usually show traces of the edges between facets where pieces of stress shell have been detached.

Oblique-ended form (Nos. 13-16, Figs. 1N to P).—Baker (1962 P1.4, Fig. 6) figured an oblique-ended aberrant specimen from Port Campbell, Victoria having a complete covering of flow ridges. He remarked: "This is one of the few well-preserved australites for which no surface can be specifically determined as

Table 2

Aberrant australites from Western Australia, Group 2

No.	Form	Collection	Locality	Dimensions (mm)	Mass (g)	S.G.
9	Flat topped	SM 10152	Mount Remarkable station	(15·1–14·7) x 9·1	2·427	2·455
10	Flat topped	SAM T411	Eastern Goldfields of W.A.	(7·2–6·8) x 5·4	0·325	2·432
11	Flat topped	JLCJ	Hampton Hill station	(8·7–8·0) x 5·8	0·505	
12	Flat topped	SM 9585	c. 90 km NNE of Haig	(18·8–18·4) x 9·2	4·051	2·457
13	Oblique ended	SM 11563	Earaheedy station	19·1 x 10·2 x 7·8	2·252	2·460
14	Oblique ended	ESS 42(ii)	Beru Pool, Yelma station	20·7 x 10·1 x 8·2	2·131	2·457
15	Oblique ended	TC	Taurus near Bulong	29·0 x 9·5 x 9·6		
16	Oblique ended	UM	Eastern Goldfields of W.A.	44·2 x 12·2(12·0) x 13·2 (11·9)	3·887	2·456
17	Complex dumb-bell	JBM	Eastern Goldfields of W.A.	40·5 x 9·8(9·4) x 9·4 (8·4)	4·326	2·446
18	Complex dumb-bell	JLCJ	Edjudina station	34·2 x 10·1(9·6) x 9·8 (9·6)	4·481	2·453
19	Complex dumb-bell	SM 12004	Menangina station	36·0 x 11·0(10·8) x 10·7 (10·5)	5·600	2·456
	Tortoise-shell ovals:					
20	Broad oval lens	JLCJ	Edjudina station	L 17·1		
21	Narrow oval canoe	SM 11775	Mount Remarkable station	19·4 x 12·4 x 8·0	1·784	2·445
22	Narrow oval lens	WAM 13116	c. 100 km N. of Haig	19·4 x 11·9 x 7·5	1·883	2·451
23	Square ended	SM 10901	Earaheedy station	20·8 x 13·5 x 11·4	4·434	2·453
24	Square ended	SM 10670	Broad Arrow	21·4 x 13·8 x 9·7	3·664	2·453
25	Square ended	JLCJ	Edjudina station	19·9 x 12·3 x 7·8	2·640	2·466
26	Square ended	SM 11704	Yerilla Station	21·4 x 13·1 x 9·8	3·830	2·455
27	Square ended	WAM 11948	Hannans Lake	25·1 x 14·7 x 11·4	5·637	2·444
28	Square ended	SM 11771	Mount Remarkable station	18·5 x 10·1 x 7·5	2·138	2·433
29	Square ended	SM 10873	Eastern Goldfields of W.A.	27·6 x 14·2 x 12·2	6·646	2·456
30	Square ended	WAM 12477	Edjudina station	23·0 x 11·7 x 9·8	3·727	2·459
31	Square ended	JLCJ	Hampton Hill station	21·1 x 10·2 x 9·2	2·807	
32	Square ended	NM	Mount Remarkable station	29·1 x 14·0 x 11·8	6·740	
33	Square ended	SM 10901	Earaheedy station	25·0 x 11·9 x 10·1	4·336	2·458
34	Square ended	WAM 13434	Edjudina station	22·3 x 10·2 x 8·8	2·653	2·459
35	Square ended	SM 12034	Edjudina station	21·0 x 13·5 x 9·0	3·210	2·447
36	Square ended	WAM 13434	Edjudina station	29·4 x 11·9 x 9·5	4·889	2·451
37	Canoe like	SM 9833	Edjudina station	24·2 x 11·9 x 10·6	3·398	2·458
38	Canoe like	JLCJ	Hampton Hill station	(>21·7) x 10·4 x 8·7	2·182	2·455
39	Canoe like	SM ...	Western Australia	(>22·4) x 9·4 x 8·0	2·049	2·448
40	Canoe like	PJS 134	Kurnalpi	(>23·2) x 9·7 x 8·6	2·333	2·443
41	Canoe like	WAM 12481	Edjudina station	26·3 x 10·0 x 9·3	3·439	2·461
42	Canoe like	UM	Eastern Goldfields of W.A.	(>25·1) x 9·5 x 8·9	2·548	2·451
43	Canoe like	SM 11755	Wangine Soak	(>24·2) x 8·8 x 7·4	1·978	2·449
44	Canoe like	SM 9502	Buningonia Soak	(>26·8) x 9·2 x 8·2	2·781	2·454
45	Canoe like	TC	15 km N. of Bulong	L 23·9		
46	Seed type	JLCJ	Edjudina station	15·1 x 11·3 x 11·1	2·200	
47	Seed type (fragment)	SM 10901	Earaheedy station	(>14·2) x 12·8 x 11·4	2·372	2·450
48	Seed type	WAM 11 944	Kalgoorlie	15·4 x 12·3 x 10·4	2·222	2·448
49	Seed type	SM 10873	Eastern Goldfields of W.A.	14·2 x 10·8 x 8·7	1·436	2·461
50	Seed type	WAM 12227	Earaheedy station	14·4 x 12·1 x 9·4	1·825	2·451
51	Seed type	JLCJ	Hampton Hill station	10·2 x 9·6 x 6·7	0·850	
52	Seed type	SM 10901	Earaheedy station	13·7 x 10·2 x 7·0	0·984	2·457
53	Seed type	JLCJ	Edjudina station	13·6 x 10·9 x 7·4	1·391	
54	Seed type	WAM 12147	Yellow Lake, Israelite Bay	11·9 x 9·4 x 6·2	0·838	2·445
55	Seed type	SAM T97	Israelite Bay	Fragment L 14·2		
56	Unnamed form	TC	Kunanalling	14·4 x 9·7 x 8·9		
57	Seed form with crinkly top	SM 10609	Menangina station	19·2 x 13·2 x 8·9	1·771	2·449
58	Pine-seed form	TC	Seven-mile Hill, Kalgoorlie	L 18·3		
59	Pod like	JLCJ	Edjudina station	25·8 x 14·2 x 11·9	0·668	2·457

the posterior or anterior surface". Although the Western Australian specimens have flow ridges on the ends only or even on a single end, they are believed to be of the same aberrant type. When on the ground, the long axis would lie parallel to the surface of the ground leading to abrasion of flow ridges from the flanks but with the possibility that some remnant of them might survive on the ends not in contact with the ground.

Specimen No. 14 is deeply etched. Fingers (Barnes 1961) stand out in relief on the major surfaces but not on the ends. Fingers may extend a few millimetres into an australite and are believed to have been primary features because they are usually observed on posterior surfaces only. The distribution of fingers on specimen No. 14 suggests that only a thin layer of glass can have been lost from the flanks but at least some millimetres from the ends. It was speculated that if an elongated primary body contained a bubble cavity centred somewhat off the mid-point of the length, it might orient as in Figure 1N1 (heavier end forward and moving towards bottom of page). When a sufficient frontal thickness had been removed, retreat of the centre of gravity could cause instability and a turning over through 180° to a complementary position; this process could be repeated. However, the specific gravities of the specimens do not suggest the presence of cavities of significant size; nor could cavities be detected using strong illumination. The sequence of the specimens in Table 2 is of increasing elongation culminating in a dumb-bell. At the same time, width/thickness declines, but this might be fortuitous as only 4 Western Australian specimens were available.

Complex dumb-bell form (Nos. 17-19, Figs. 1Q, R). —Specimens have flow ridges over the entire surfaces with strong tendency to longitudinal pattern. The width/thickness is close to unity (Table 2) i.e. they approach the "peanut" form (Fenner 1934) which is nearly circular in section and therefore has much the same appearance in posterior as in side view. Less constant features are slightly concave ends (Fig. 1Q2) and a distribution of flow ridges suggestive of changes in flight orientation.

Tortoise-shell ovals (Nos. 20-22, Figs. 1S to U).—Oval lenses and the flanged forms from which they were derived sometimes have a coarse pattern of ridges, evidently flow ridges, upon their posterior surfaces. There may be a strong tendency to longitudinal pattern. Nothing quite comparable has been observed on round forms or on those more elongated than narrow oval.

Square-ended form (Nos. 23-36, Figs. 2A to G).—With the possible exception of the seed type, this is the commonest of all the aberrant forms noted in Western Australia. About 30 specimens were examined but most were severely etched or abraded and lacked all surface detail. The better-preserved specimens show complex flow ridges or roughly longitudinal ridges approximating to seed type (see below) on the anterior surface and flanks (Figs. 2A2, D1, G2), but the most characteristic feature is the way in which the supposed posterior surface rolls down to meet ends which are at right angles to the length (Fig. 2D2). The survival of the characteristic shape even after all surface detail has gone (Figs. 2B, C, E, F) has increased the abundance of this form relative to those such as the crinkly top from which the removal of glass a few tenths of a millimetre thick effectively destroys them as aberrant forms.

Canoe-like form (Nos. 37-45, Figs. 2H to M).—This form is of moderate abundance amongst aberrant types (15 inspected, most of them too worn to be informative). One specimen of this form was figured by Fenner (1934, Pl.8, A5e 1 and 2) but his other figured specimen (A5e 3 and 4) looks more like a normal form derived from the saddle region of a symmetrical dumb-bell rather than a canoe-like form. Fenner placed these specimens under the general heading of canoes in a sub-class termed "aberrant elongates". Characteristics of the canoe-like form are the high elongation in combination with roughly equidimensional cross-section; flow ridges tending to longitudinal on the supposed posterior surface and often on the anterior surface also if not abraded (Fenner 1934 noted "flow lines on both surfaces"); and the pinched and slightly turned ends (presumably backwardly turned), one or both of which are likely to be found in broken condition.

Seed type (Nos. 46-55, Figs. 2N to R).—Fenner (1940 Pl. 19, No. 14) figured an australite as the "seed type", the essential feature being the arrangement of the flow ridges and troughs on the anterior surface. The pattern resembles that of meridians of longitude radiating from the two blunt ends of the length as poles (Fig. 2N). The most typical specimens have low elongation and the resemblance of the pattern to meridians is then emphasized. Baker (1969) figured and described as the "nut-like" form specimens in which the flow ridges encroached on to what would normally be the posterior surface, tending towards an almost complete surface coverage by flow ridges and troughs. He postulated that rocking on the long axis had exposed parts of the posterior surface. If both seed and nut-like names are to be retained, then the nut-like form could perhaps be confined to this less common variety with flow ridges distributed around more than 180° of the cross-section; only two of the specimens examined showed this feature (Fig. 2Q). There is variation in width/thickness from about 1.7 (shallow forms) to about 1.0 (globular, especially the nut-like forms—see proportions of those illustrated by Baker 1969, Fig. 3). Three other specimens showed what appeared to be very small remnants of the butt of a flange but this could not be confirmed. Two specimens showed not only the seed-type flow ridges but concentric ridges on the other major surface, apparently as the result of overturning and re-establishing at least some degree of stability (Figs. 2O, P). The sequence of development of these two anterior surfaces is not evident. Seed-type flow ridges are present also on No. 8 of Group 1 and on a rare broad oval form with pointed ends (No. 56, Fig. 2R). Specimens with a crinkly top (Fenner 1934) may occasionally have a seed-type anterior surface. Thus the seed-type pattern is present on a considerable variety of forms having various kinds and degrees of instability ranging from a rocking to complete over turning. There is doubt that it should be regarded as an aberrant form but perhaps rather as one of the less common but by no means rare patterns of flow ridges.

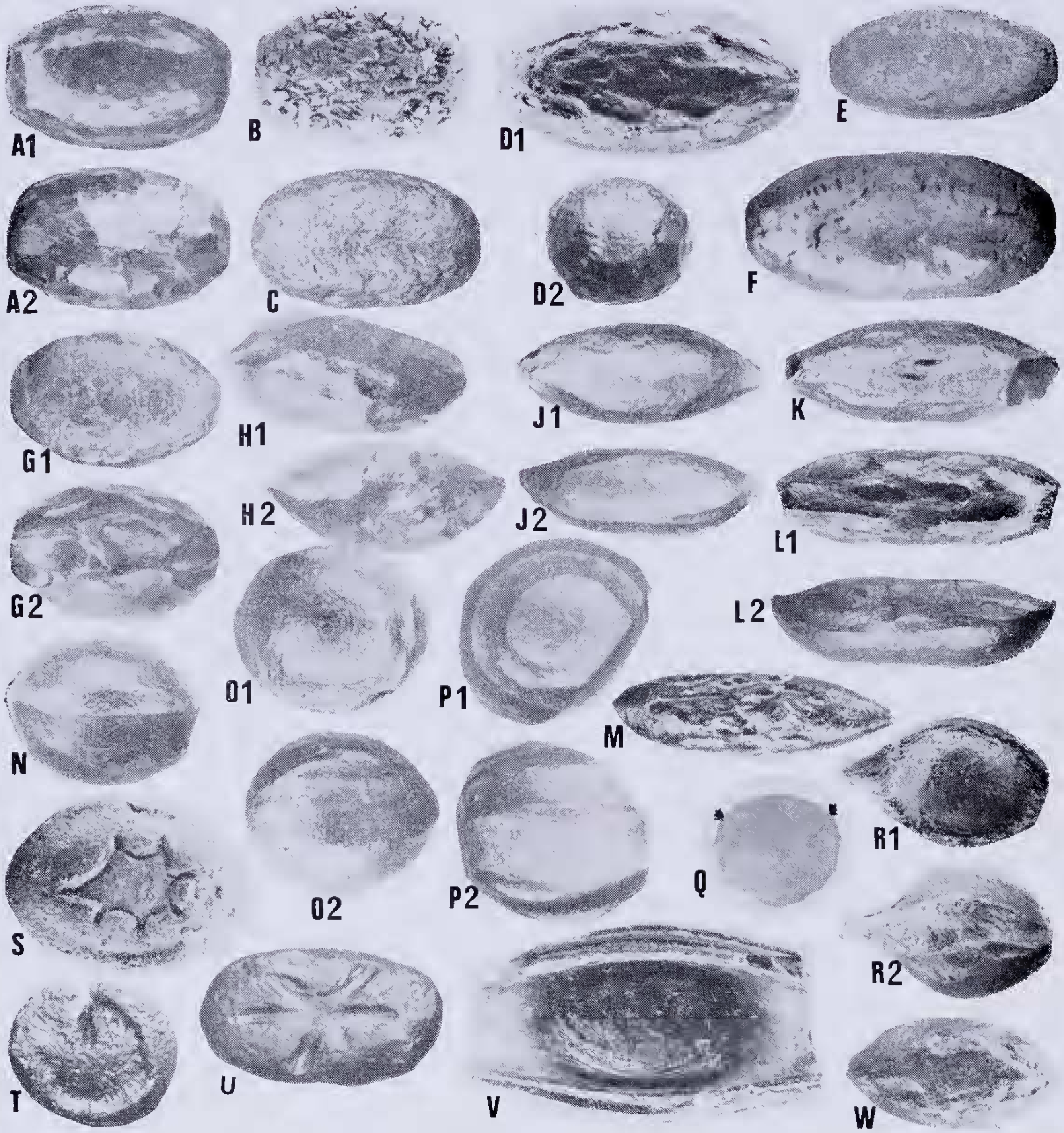

Figure 2.—Aberrant australites from Western Australia. For dimensions and key to specimen numbers see Table 2. In side or end (elevational) views direction of flight is towards bottom of page. If the view is not specified flight orientation is uncertain or unknown. A1.—No. 24, posterior surface. A2.—No. 24, anterior surface. B.—No. 23. C.—No. 26. D1.—No. 29, anterior surface. D2.—No. 29, end view. E.—No. 31. F.—No. 32. G1.—No. 35, posterior surface. G2.—No. 35, anterior surface. H1.—No 37, posterior surface, broken at upper right. H2.—No. 37, side view. J1.—No. 40, posterior surface. J2.—No. 40, side view. K.—No. 42. L1.—No. 44, posterior surface. L2.—No. 44, side view. M.—No. 45. N.—No. 49, anterior surface. O1.—No. 50, surface with concentric ridges. O2.—No. 50, surface with seed-type flow ridges. P1.—No. 55, surface with concentric flow ridges. P2.—No. 55, surface with seed-type flow ridges. Q.—No. 47, broken end ground flat. Flow ridges are present from the arrow-head at about 2 o'clock clockwise to the arrow-head at about 10 o'clock. R1.—No. 56, posterior surface. R2.—No. 56, anterior surface. S.—No. 57, posterior surface. T.—Broad oval lens, posterior surface, length 16 mm, from about 95 km NNE of Haig, SM 11028. U.—Narrow oval lens, posterior surface, length 24.4 mm, Earaheedy station, SM 10943. V.—No. 58, posterior surface. W. No. 59.

Other forms

The following were omitted from detailed listing because of the small numbers available, poor state of preservation, or doubts about identification as aberrant forms.

Crinkly top (No. 57, Fig. 2S).—The distinctive feature was defined by Fenner (1934). The crinkly top has usually been regarded as comprising thin tongues of secondary melt which have overflowed on to the posterior surface from various points around its edge, but I have been unable to detect any junction line between the supposed flows and posterior surface. It is suggested that the crinkly top might develop by removal of material from the central part of the posterior surface rather than by addition of material to the peripheral part. Shallow depressions may be developed by weathering of posterior surfaces (Fig. 2T). Radial systems of grooves, especially V-grooves centred upon posterior poles are common and might provide the starting point. An oval specimen (Fig. 2U) on which the grooves have widened into shallow U-grooves and the "front" has retreated may be an intermediate stage in formation of a crinkly top. If crinkly tops developed in that way, they need not be regarded as aberrant.

Pine-seed form (No. 58, Fig. 2V).—The form was defined by Skeats (1915). It has a relatively flat posterior surface with broad and extensive flange at the ends merging into narrow, backwardly-curved flange along the sides; these are essentially exaggerated canoe features. The process which forms a canoe could also form the pine seed, the flat top possibly resulting from the considerable loss of material from the body to provide the end-flange.

The frail end-flanges of pine-seed forms have usually been either folded backward to be partially or wholly fused to posterior surface (Cleverly 1973, Fig. 2-24 and Pl. 1-24 and -35) or broken off during weathering (Fig. 2V).

Pod-like form (Baker 1969).—The specimen available (No. 59, Fig. 2W) is in only fair condition, and other possible examples are worse.

Discussion

Most of the aberrant australites examined are relatively small; only two of them weigh more than 10 g. The mode of the masses is in the 2 g - 3 g interval (Fig. 3A), but the distribution is skewed to masses greater than 3 g when compared with a general sample from the area. This shows up in the distinctly higher mean mass of 3.54 g compared with 2.89 g for 3562 complete or essentially complete australites from Earaheedy, Hampton Hill, Edjudina and Mount Remarkable stations.

The specific gravities of occasional aberrant specimens were determined initially because it was speculated that a large bubble cavity, appropriately located, might cause some instability or peculiarity flight and hence the development of an aberrant form. No unusually low result was obtained and when a relative frequency diagram was prepared, its degree of agreement with that for other australites of the area was remarkable (Fig. 3B). Note that this is not the usual random sample comprising australites of all morphological types and sizes from a localized area; on the contrary, this sample is highly biased to the 2% or so of aberrant types

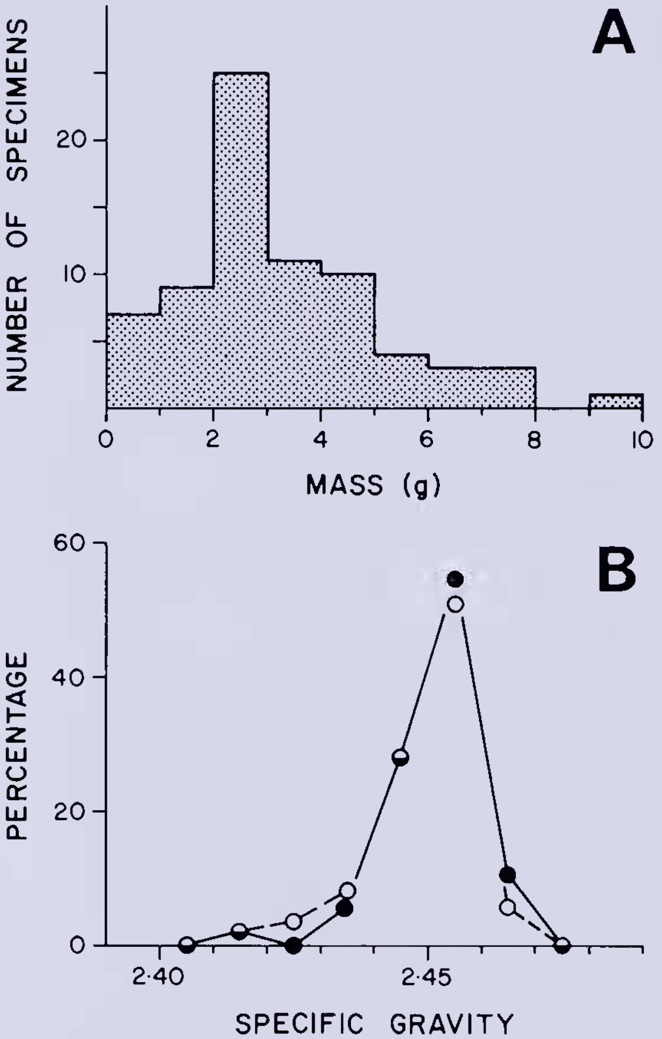

Figure 3.—A.—Masses of 73 aberrant australites with mode in the 2-3 g interval. Single specimens of 12.3 g and 15.1 g have been omitted. B.—Relative frequency polygons of specific gravity. Polygon for 56 aberrant australites shown by solid circles and firm lines. Polygon for 420 australites from the Kalgoorlie area from Chapman *et al.* (1964) shown by open circles and broken lines.

occurring throughout a considerable region. It appears that the aberrant australites of the region are thoroughly typical as regards specific gravity, being representative of the whole range and in the same proportions as "normal" forms. Reasons for the peculiarites of aberrant australites needs to be sought in other properties.

The dimensional proportions of a form are concerned in determining such things as its flight orientation, the amount of cross-sectional area relative to mass and the depth below the frontal surface of the centre of gravity. In combination with the frontal curvature, these affect the stability of a body in ablation flight and the course of its development. Various plots were made of the dimensions and their ratios such as length/width (elongation) and width/thickness. Because the number of specimens of any type is generally small, these plots showed little that cannot be seen in the tabulated dimensions and they have not been included. However, the fields on those diagrams might eventually be useful for defining some of the forms, especially after additional specimens from elsewhere have been studied. Thus the oblique-ended form combines increasing elongation (1.87-3.62) with decreasing width/thickness (1.31-0.92); the canoe-like form is of high elongation (2.03-2.91) with small width/thickness (1.08-1.24) in conformity with the observation that some specimens of that type are almost cylindrical in the mid-section. The complex dumb-bell form has very high elongation (3.27-4.13) in combination with width/thickness about 1.04 ("peanut type"). However, it would appear pointless to apply this consideration of dimensions to the seed type because the structure can occur on a wide variety of forms; it might not apply to the crinkly top either as that structure evidently occurs on specimens ranging from round to boat shaped (Fenner 1934, P1. 9F). It might be advantageous to recognise two kinds of aberrant types in Group 2. On the one hand there are the surface features such as the seed-type flow-ridge pattern and the crinkly top which are of secondary or even later origin and which are shallow enough to be removed during erosion; on the other hand there are the shapes such as the square ended which have a high capacity for survival after all surface detail has gone, and for the origins of which it might be necessary to go back to the consideration of primary forms.

It is conceivable that some kinds of aberrant australites occur in certain regions because their development was related to factors such as distance from source. Information on eastern Australian aberrant australites is, however, exceedingly meagre. From personal observation, excellent examples of tortoise-shell ovals, square-ended and canoe-like forms as well as a number of seemingly unique specimens (Group 1) have been found in parts of South Australia (Australian and South Australian Museum collections).

Some of the specimens of the Shaw collection placed by Fenner (1930) in sub-classes A7e and A5e appear to be aberrant and the Shaw collection is generally thought of as being from the Nullarbor Plain spanning parts of Western and South Australia. However, it is quite clearly stated (Fenner 1930, p.65) that the majority were found in the vicinity of Israelite Bay which is in Western Australia and about 270 km outside the south-western margin of the Nullarbor Plain. Figures from the Shaw collection are not therefore pertinent to a consideration of australites from eastern Australia.

For the Kennett collection from the general vicinity of Charlotte Waters, Fenner (1940, p.315) has given a list from which some items may be eliminated to leave, at most, 37 aberrant australites out of about 5400 identifiable specimens, or about 0.7%. This low percentage is in accord with the writer's experience of australites from that general area. The detail of those specimens apart from two (three?) illustrated ones is not given.

Baker (1969) recorded pod-like and nut-like forms from Mulka, South Australia, but it is peculiar that in the voluminous and detailed literature which Dr Baker produced on Victorian australites he should say so little of aberrant ones. The impression is gained that aberrant forms are more abundant on the western than on the eastern side of Australia but information is so meagre that this is little more than speculation. Some account of the aberrant australites of South Australia and the eastern states is needed, and particularly so because the better-preserved specimens of Victoria and parts of South Australia should provide better opportunities for determining the mechanisms of development.

Acknowledgments.—I thank the following persons who are curators or owners of australite collections, for the loan of specimens:—Mr D. E. Davidson, Mr J. L. C. Jones, Mr M. H. Lloyd, Professor J. F. Lovering, Dr K. J. McNamara, Ms N. Moylan, Dr C. Pearson, Ms J. M. Scrymgour, Mr P J. Simmons, Mr and Mrs R. G. Tillotson and Mr L. D. Tillotson. I thank also Ms J. Wearne for drafting the line diagrams and Mr M. K. Quartermaine for processing my photographs.

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